



International Civil Aviation Organization

MULTILATERATION & MAGS

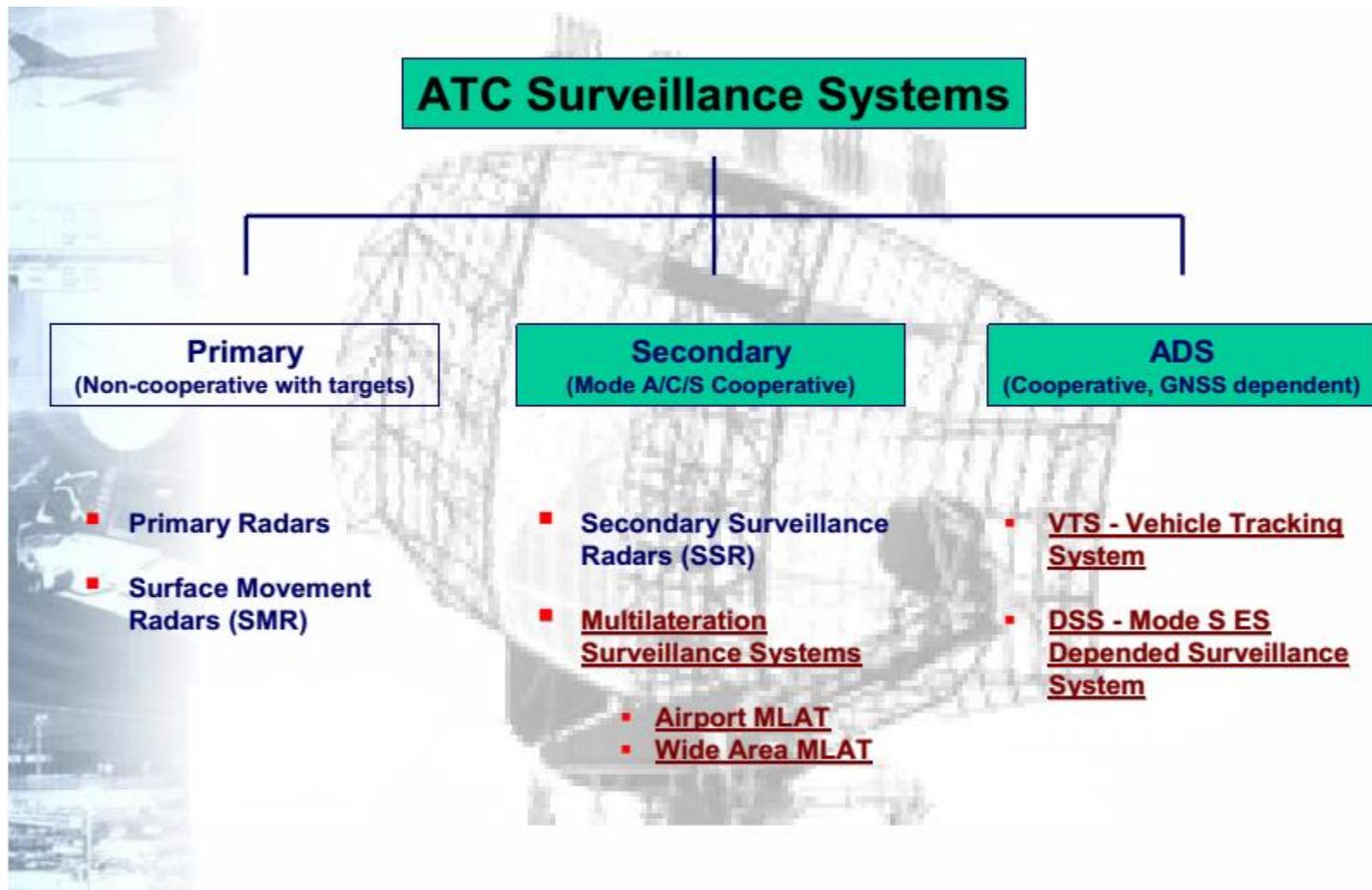
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OUTLINE

1. Principle of multilateration
2. Aircraft signal
3. Multilateration on airports
4. Conclusion

Systems Classification





1. Principle of multilateration

Basic principle of Multilateration

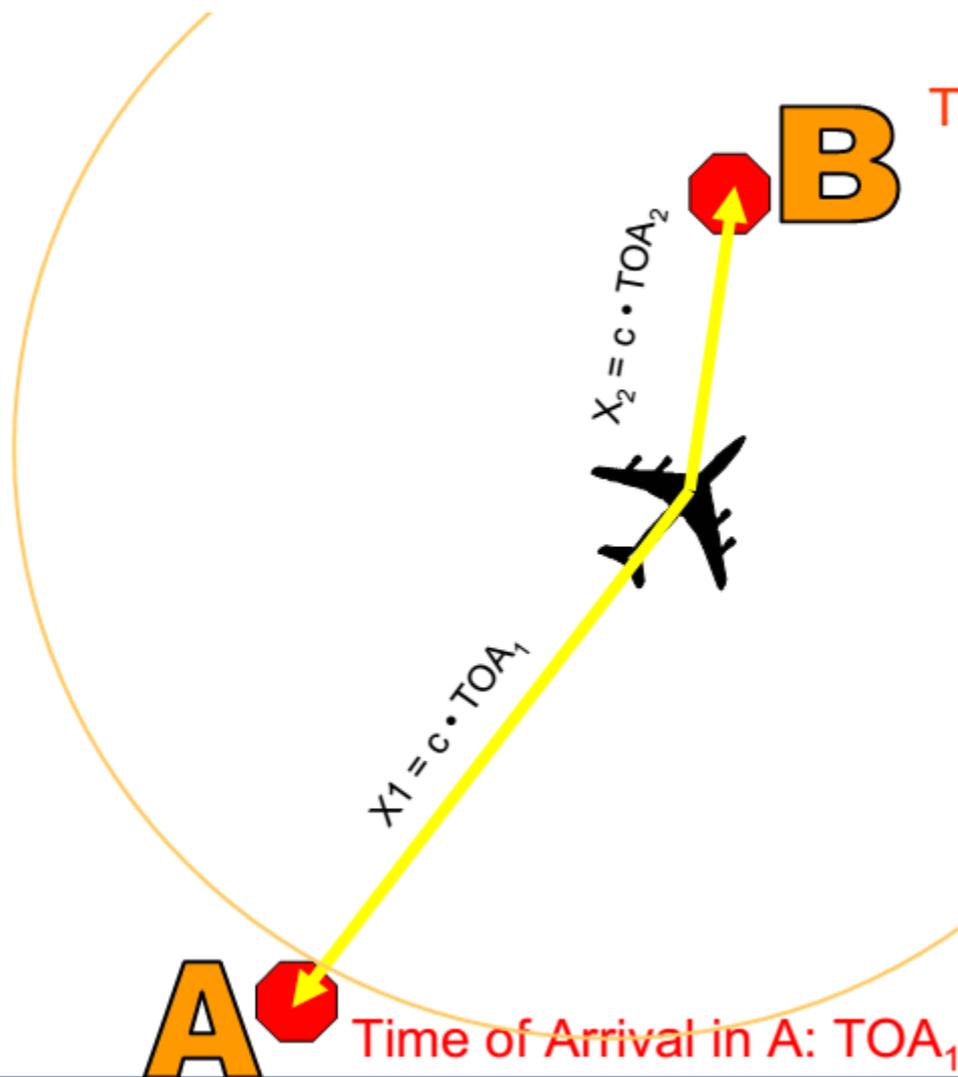
Multilateration (MLAT) is a technique initially developed for military applications, which allows to passively locate co-operative targets by multistatic measurements.

- Passive: no interrogation from the surveillance system are required (i.e. receive only), provided the aircraft transmits a signal
- Co-operative: the principle requires appropriate onboard equipment (e.g. a transponder)
- Multistatic: The same signal needs to be received simultaneously by several ground stations

Comparison with other Surveillance Principles

Surveillance Principle	Onboard equipment required?	Interrog. required?	Data measured by surveillance system?
Primary Radar	No non-co-operative	Yes active	Yes independent surveillance
Secondary Surveillance Radar	Yes co-operative	Yes active	Yes (partly) partly independent surveillance
Mode A/C Multilateration	Yes co-operative	Yes active	Yes (partly) partly independent surveillance
Mode S Multilateration	Yes co-operative	No passive	Yes (partly) partly independent surveillance
ADS-B	Yes co-operative	No passive	No dependent surveillance

Principle of Multilateration Systems (1)



A and B are a pair of Ground Stations receiving both a signal from an aircraft.

The Time of Arrival TOA of the signal is measured by each Ground Station.

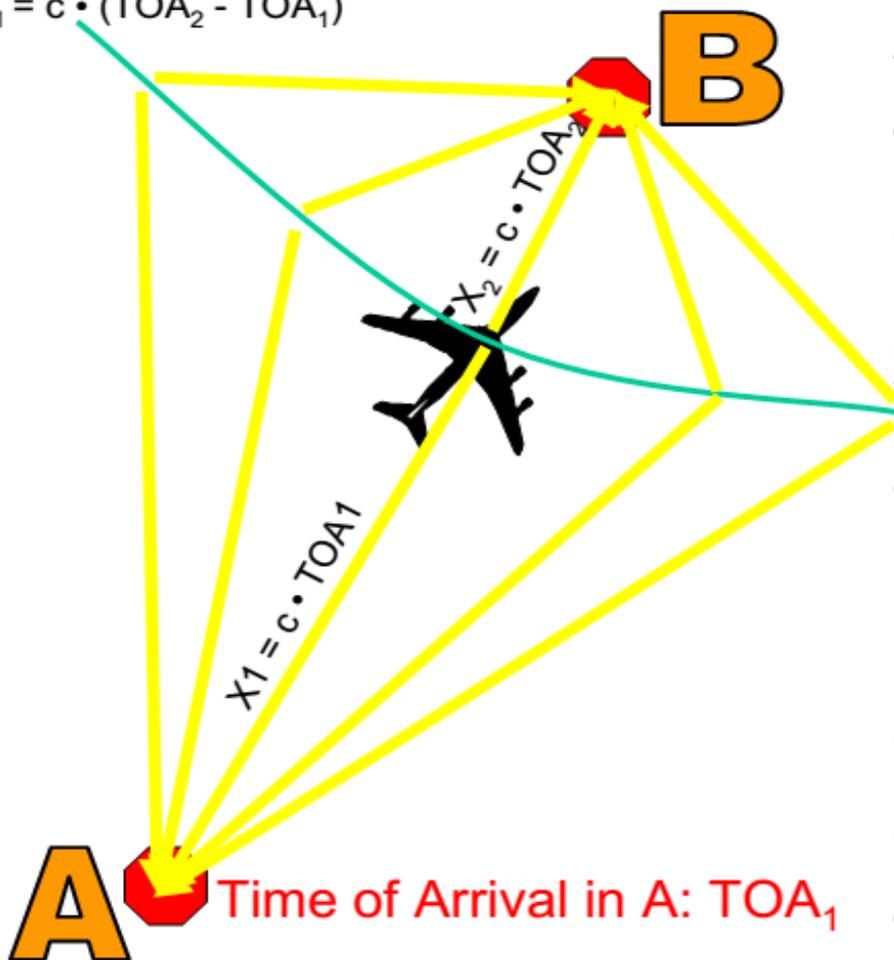
The time difference $TOA_1 - TOA_2$ corresponds to the distance difference

$$X_2 - X_1 = c \cdot (TOA_2 - TOA_1)$$

Principle of Multilateration Systems (2)

Time of Arrival in B: TOA_2

$$X_2 - X_1 = c \cdot (TOA_2 - TOA_1)$$



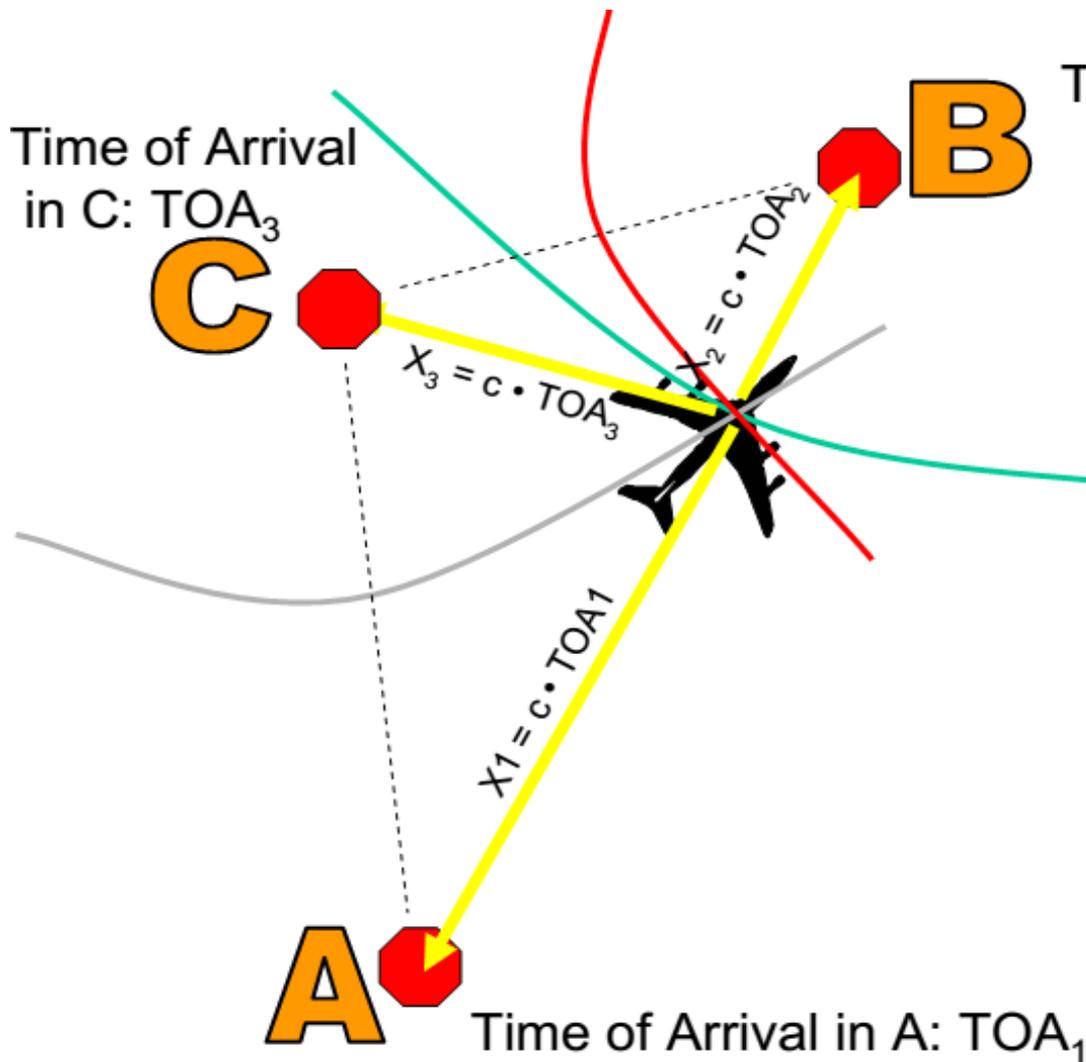
At a given time, the Aircraft is on the locus of points having the distance $X_2 - X_1$ constant:

$$X_2 - X_1 = c \cdot (TOA_2 - TOA_1)$$

This is a hyperbola (curve in blue)

=> Two ground stations allow to determine one hyperbola where the aircraft is located

Principle of Multilateration Systems (3)



A third station in C gives two more differences

$$X_2 - X_1 = c \cdot (TOA_2 - TOA_1)$$

$$X_2 - X_3 = c \cdot (TOA_2 - TOA_3)$$

$$X_1 - X_3 = c \cdot (TOA_1 - TOA_3)$$

and thus allows to determine two more hyperbolas

=> The aircraft is located at the intersection of the three hyperbolas

Multilateration Principle Summary

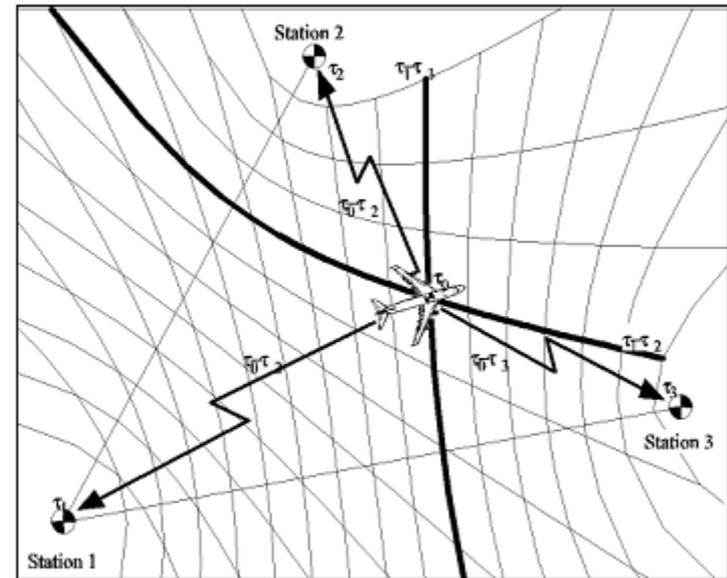
Signal transmitted by aircraft transponder is received by several ground stations (a minimum of 3 for 2D position) in the vicinity

Ground stations determine the precise time of arrival (TOA) of received signals

TOA difference is calculated for each pair of ground stations

Knowing the speed of wave propagation, a hyperbolic line of position results

Intersection of several hyperbolas is the target position



This principle can be extended to measure 3D positions : a 4th ground station is then required

Generic System Architecture

To implement the principle of multilateration system, the generic system architecture consists of:

- A sufficient Number of Ground Stations (GS) capable of:
 - receiving the signal(s) from aircraft located in the service area,
 - measuring the time of arrival and forwarding the TOA to a central station,
 - being synced to the same timebase
- A Central Processing Station (CPS):
 - to receive the TOAs from the Ground Stations and
 - to compute the aircraft position from the set of measurement.
 - In addition the CS has to manage the fact that several aircraft can be located in the service area,
- A communication network to link all the GS to the CS

Constraints related to the principle of multilateration systems



The measurement of time of arrival must be very accurate

- As an inaccurate measurement will degrade the accuracy of the position calculation
- This can be achieved by high frequency sampling of incoming signals

The clocks of the ground stations must be very well synchronised

- As a bias between GS clocks will imply a measurement error
- This can be achieved by several means :
 - transmission of a calibration signal
 - use of an universal common time reference signal (regional time signal transmitter, GPS)



2. Aircraft Signal

Cooperative Target

Unequipped aircraft will not be seen by the MLAT system.

Only cooperating targets will be detected.

For civil aviation, the signal transmitted by aircraft can be:

- either a Mode A/C or Mode S reply to any interrogator in the neighbourhood (e.g. Radar, ACAS)
- the Short Squitter (acquisition squitter for ACAS) transmitted once per second for aircraft equipped with a Mode S Transponder
- In the next future, the Extended Squitter transmitted twice per second for ADS-B equipped aircraft.

In case the aircraft are not equipped with Mode S transponders, and no MSSR are available in the neighbourhood, a specific interrogator must be implemented to trigger Mode A/C replies.

Aircraft Signal which can be used by multilateration



Transponder transmission	When sent	Original purpose	Data contents	Use today
Mode A/C reply	Sent in response to interrogation	Ground ATC surveillance and ACAS	Mode A or Mode C code depending on interrogation	Very widespread
Mode S reply	Sent in response to interrogation	Ground ATC surveillance and ACAS	24bit aircraft address. The rest depends on interrogation	Expanding (few ground Mode S interrogation) Mode S replies widespread due to ACAS mandate
Acquisition squitter « short squitter »	Once per second	ACAS	24bit aircraft address and transponder capability	Widespread due to ACAS mandate
ADS-B Extended Squitter	Various rates up to 2 per second	ADS-B	24bit aircraft address and the rest is variable	Implementation is just starting

Difference between processing Mode S and Mode A/C aircraft



With Mode S signals, each ground station receives a signal which is uniquely identified by the ICAO 24 bits address; this allows the MLAT system to unambiguously associate the various messages as belonging to the same aircraft

For Mode A/C signals, the association is easy if the signal is a Mode A signal, but if it is a Mode C signal, the MLAT system must maintain a table of all aircraft in the service area before being sure to associate the replies received by ground stations as belonging to the same aircraft.



Identification of aircraft (1)

In civil applications, identity of the aircraft is required

MLAT extracts aircraft identity information from the transmitted signal (also used to measure aircraft position)

This is obtained by Mode A information when the signal is a reply to MSSR or Mode S interrogation

Identification of Aircraft (2)

The identification is not straightforward in case no Mode S or MSSR radars are implemented in the neighbourhood.

If the aircraft is equipped with a Mode S transponder it transmits the short squitter, including the 24 bits ICAO address of the aircraft

- The 24 bits ICAO address is currently not included in Flight Plans
=> does not allow to correlate the signal with aircraft ID
- The MLAT must then interrogate the aircraft to obtain Mode A information
- This will no longer be true with Extended Squitter as the Call Sign is transmitted by Extended Squitter

If the aircraft is equipped with a MSSR transponder, the MLAT system must interrogate the aircraft to obtain a Mode A reply.

Aircraft Altitude

In the same manner as for identity, aircraft barometric altitude will be obtained by using Mode C.

In the case of 3D MLAT system, only the geometric altitude of the aircraft is measured :

- Not used in “normal” surveillance operation
- Used in monitoring of the performance of aircraft altimeters, for example in the case of RVSM implementation. In this case a modelling of the variation of atmospheric pressure with altitude must be established

ADS-B provides barometric and geometric Altitude



3 - Conclusion

Airport Multilateration Summary

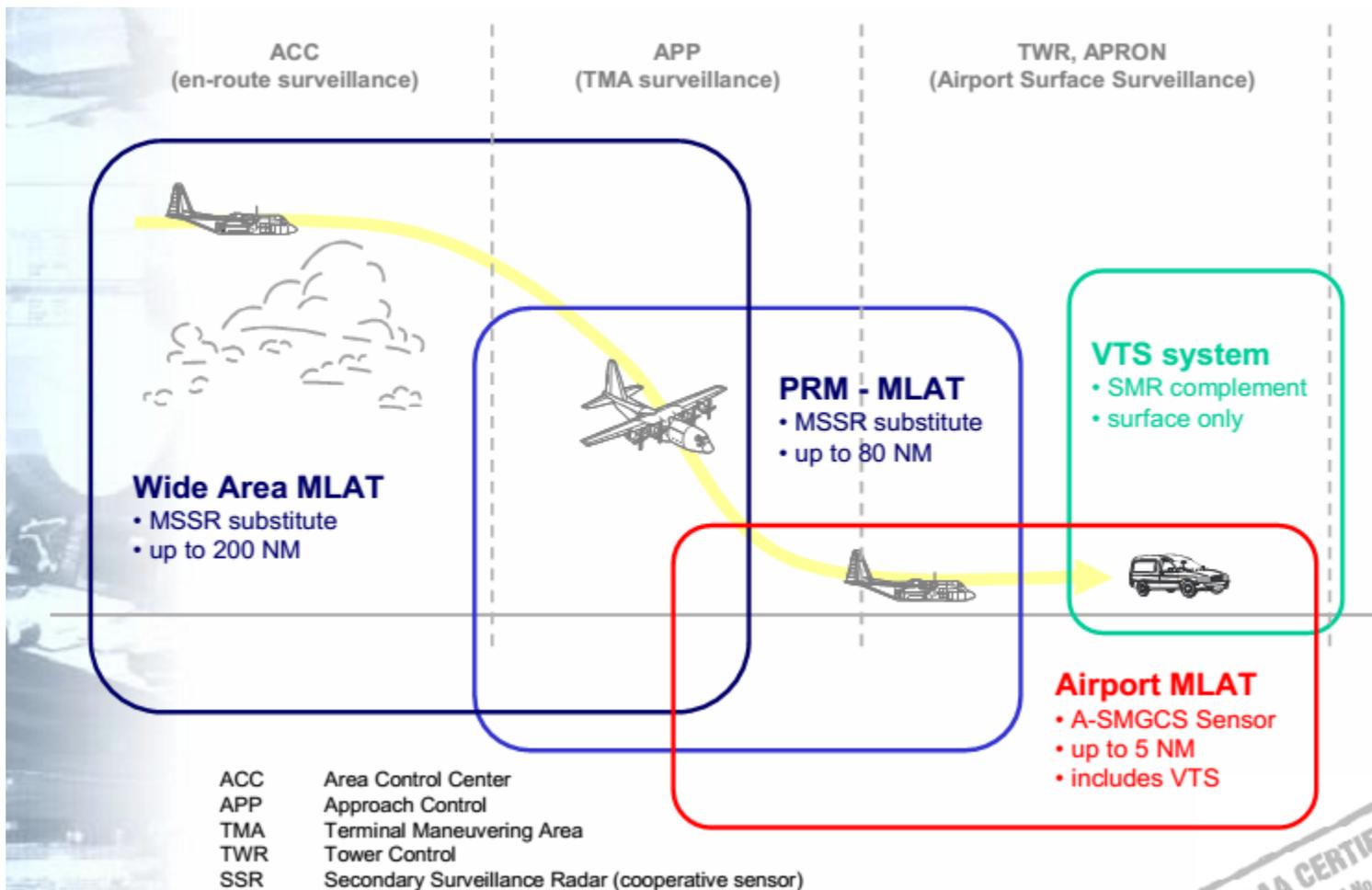
Strengths

- High performance
 - For airports, it exceeds present SMR performance
- No additional aircraft equipage required
 - Aircraft widely equipped with SSR transponders
 - More and more aircraft are equipped with Mode S Transponders
- Lifecycle cost lower than Radar
 - no rotating machinery, essentially maintenance-free

Weaknesses

- Performance affected by ground effects (multipath, shadowing, etc)
- Change in installations and procedures may be required
 - So transponder is not disabled on the ground

MLAT Systems Applications



AA CERTIFIED
No. S-7

Features & Benefits of MSS

- **Unambiguous aircraft and vehicles identification**
- **High accuracy and update rate**
- **Independent height measurement (truly 3D system)**
- **Seamless airfield and airspace surveillance**
- **Independent from any external signals (GPS etc.)**
- **ADS-B processing and surveillance**
- **Simple and reliable solution of receiving stations**
- **Open Architecture - Scalability**
- **Low installation, operation and maintenance costs**



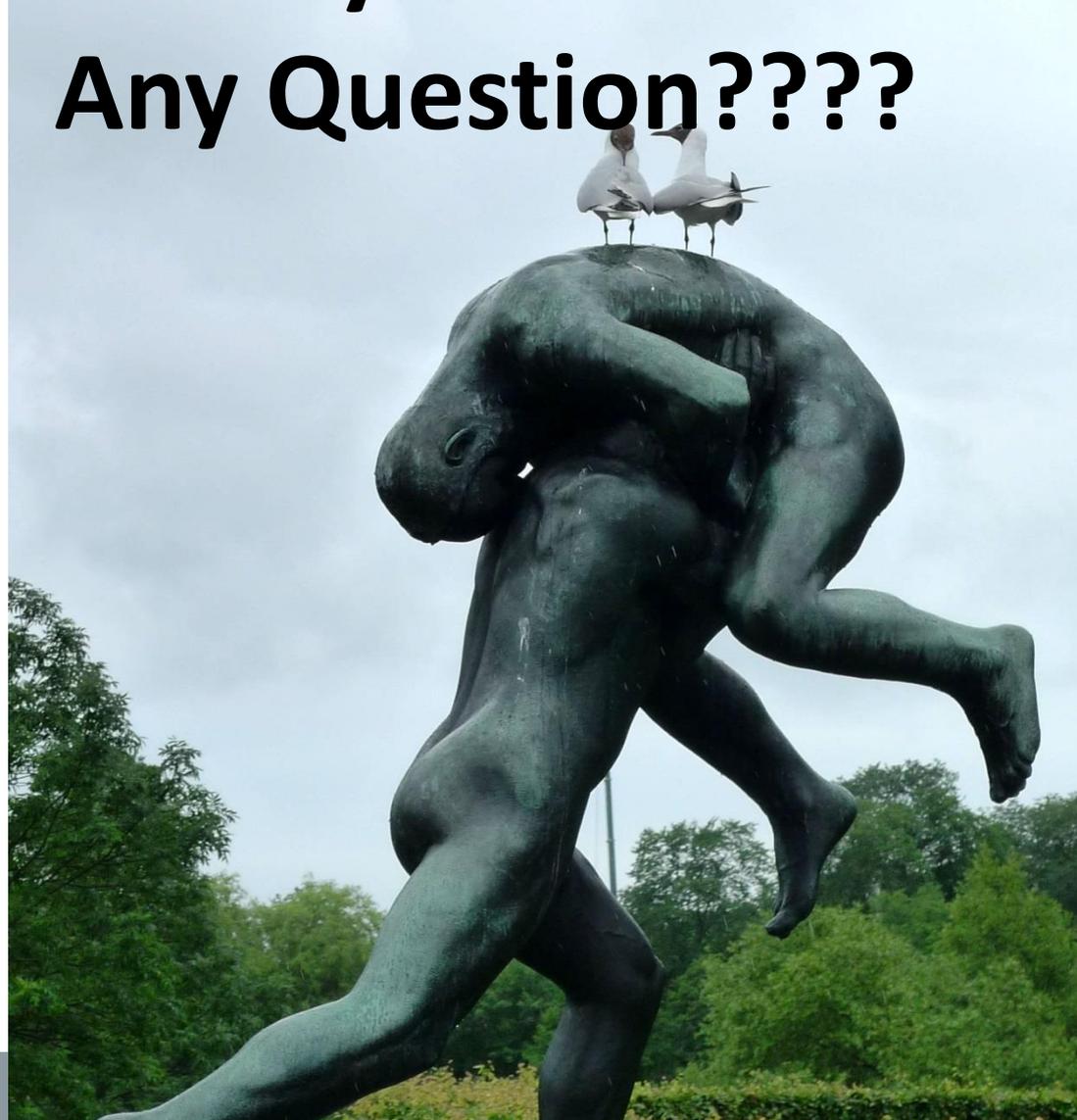
ACRONYMS

- ADS-B : Automatic Dependence Surveillance Broadcast
- COTS : Commercial Off The Shelf
- CS : Central Station
- DPX : Duplexer
- GSR : Receive only Ground Station
- GST : Transmit only Ground Station
- HDOP : Horizontal Dilution of Precision
- ISDN : Integrated Service Digital Network
- MAGS : Mode S Airport Ground Sensor
- NTA : Network Terminal Adapter
- RWY : Runways
- RXU : Receiver Unit
- SNMP : Simple Network Management Protocol
- SPB : System Processing Board
- SPC : System Processing Computer
- SSR :Secondary Surveillance Radar
- TOA : Time Of Arrival
- TWY : Taxiway
- TXU : Transceiver Unit



Thank you for your Kind attention !

Any Question????



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